

0.1 Model Configuration

The numerical calculations presented here employ a coupled ocean sea-ice configuration of the MIT General Circulation Model (MITgcm) [16]. The MITgcm configuration used covers a limited area Arctic domain that has open boundaries at $\approx 55^\circ\text{N}$ in the Atlantic and Pacific sectors. The exact boundary lines coincide with grid cells in a global cube sphere MITgcm configuration [17]. This global configuration is used to provide monthly boundary conditions of potential temperature, salinity, flow and sea-surface elevation to the simulations presented in this paper.

The grid covering the Arctic domain is locally orthogonal and has a variable horizontal resolution with an average spacing of $\approx 18\text{km}$. The mesh resolves major Arctic straits, including many of the channels of the Canadian Archipelago. The sea-ice and ocean equations are solved on the same horizontal mesh. The height based gridding option of MITgcm is utilized for the ocean vertical grid and vertical spacing is set to vary from 10m near the surface to $\approx 450\text{m}$ at a depth of $\approx 6\text{km}$. The vertical resolution is greatest in the upper ocean, with 28 vertical levels in the top 1000m. Bathymetry is derived from the U.S National Geophysical Data Center (NGDC) two-minute global relief dataset (ETOPO2), which uses the International Bathymetric Chart of the Arctic Ocean (IBCAO) product for Arctic bathymetry. The ETOPO2 data is smoothed to the coupled model horizontal mesh and mapped to the ocean vertical levels using a “lopped cell” strategy [2], which permits accurate representation of the ocean bottom boundary.

0.1.1 Boundary and initial conditions

Initial ocean hydrography is taken from the Polar science center Hydrographic Climatology (PHC) 3.0 database [21]. Initial sea-ice distributions are taken from the Pan-Arctic Ice-Ocean Modeling and Assimilation System datasets [24]. Atmospheric state (10-m surface winds, 2-m air temperatures and humidities and downward long and short-wave radiation) is taken from the six-hourly datasets of the National Centers for Environmental Prediction reanalysis [6]. Monthly mean estuarine fluxes of fresh water are based on the Arctic Runoff database [12, 20].

0.1.2 Model parameters

The ocean component is configured to use an equation of state formulated according to [11]. Ocean surface fluxes (in the absence of sea-ice) are calculated using bulk formula according to [13]. Boundary layer and convective mixing in the ocean is parameterized according to [14]. Background vertical diffusivity of temperature and salinity is set to $3.6 \times 10^{-6} \text{m}^2 \text{s}^{-1}$. An enhanced vertical diffusivity of $1.1 \times 10^{-4} \text{m}^2 \text{s}^{-1}$ is active at depth motivated by [4]. Tracer transport equations are solved using a high order monotonicity-preserving scheme [5]. Non-linear momentum terms are solved using a vector invariant formulation

[1] with viscous dissipation following [15], but modified to dissipate divergence as well as vorticity [7].

The sea-ice component of the coupled system follows the viscous plastic rheology formulation of [8] with momentum equations solved implicitly on a C-grid [3] using a procedure based on [23]. Fluxes of momentum into ice due to the overlying atmospheric winds and momentum fluxes between sea-ice and the ocean are calculated by solving for the momentum balance at each surface grid column [10]. The freezing and melting of sea-ice and associated fluxes of heat and fresh water between the ocean, sea-ice and atmosphere are calculated by solving a heat balance equation for each surface grid column at each time-step [22, 9, 18, 19]. The ocean sea-ice coupled system is stepped forward synchronously with a time-step of 1800s.

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